Encyclopedia of Electronics

2nd Edition

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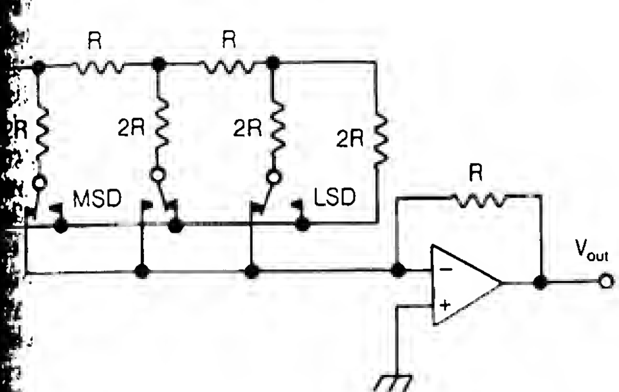
le of converting a digital signal to a time-varying signal. The classical approach to converting a signal to an analog signal has been the binary-ted method. The circuit illustrated consists of a of switches with an operational amplifier used as er. The switch for a particular bit is closed for logic opened for logic 0. The diagram shows the position switches for the binary number 0101.

overcome the difficulty in matching resistors in greater than about 20:1, the R-2R ladder network eveloped. Only two different resistor values are in this circuit. Each switch has a single-pole, throw (SPDT) form that connects the 2R leg to the reference voltage Vref or ground. The inverted adder concept adapts the circuit to semiconductor and fabrication. The DAC produces a voltage that portional to the product of the digital input and the nce voltage.



AL-TO-ANALOG CONVERTER: The inverted R-2R digital-log converter is the most popular D to A circuit. MSD is the significant digit, LSD is the least significant.

GITAL ANSMISSION SYSTEM

ystem that transfers information by digital means is tal transmission system. The simplest digital trans-on system is a Morse code transmitter and receiver, with the attendant operators. Computers commu-e by digital transmission.

nalog signals, such as voice and picture waveforms, e transmitted by digital methods. At the transmit-tation, an analog-to-digital converter changes the to digital form. This signal is then transmitted, and eceiver employs a digital-to-analog converter to e the original analog signal.

igital transmission provides a better signal-to-noise over a given communications link, than analog mission. This results in better efficiency. *See also* G-TO-DIGITAL CONVERTER, DIGITAL MODULATION, DIGITAL-TO-G CONVERTER.

MER

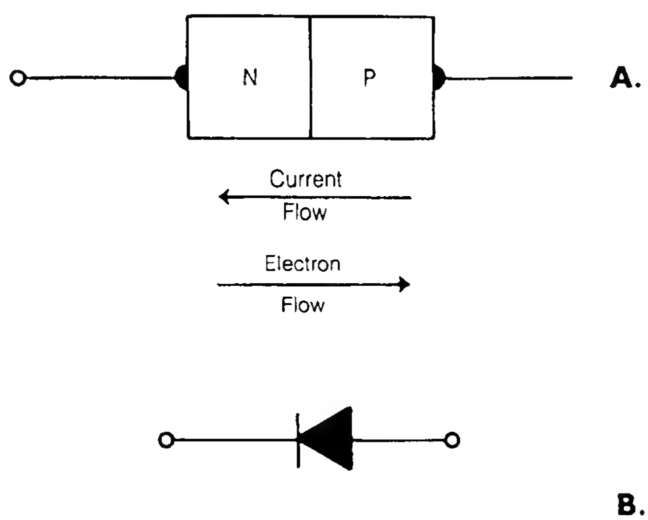
mer is a device that controls the voltage supplied to lights. The circuit may be a simple potentiometer, although a true dimmer usually provides a voltage that does not depend on the resistance of the load.

Dimmers are used in household light switches. They can control the level of illumination by regulating the alternating-current voltage. Generally, the voltage can be set at any desired value from 0 V to 120 V. Dimmers can use diacs or triacs to provide a voltage drop. The dimmer is similar in design to a motor-speed control. *See also* DIAC, TRIAC.

DIODE

A diode is a tube or semiconductor device intended to pass current in only one direction. The semiconductor diode is far more common than the tube diode in modern electronic circuits. The drawing at A shows the construction of a typical semiconductor diode; it consists of N-type semiconductor material, usually silicon, and P-type material. Electrons flow into the N-type material and out of the P terminal. The schematic symbol for a semiconductor diode is shown at B. Positive current flows in the direction of the arrow. Electron movement is contrary to the arrow. The positive terminal of a diode is called the anode, and the negative terminal is called the cathode.

Semiconductor diodes are used for many different purposes in electronics. They can be used as amplifiers, frequency controllers, oscillators, voltage regulators, switches, and mixers. *See also* DIODE ACTION, DIODE CAPACITANCE, DIODE CLIPPING, DIODE DETECTOR, DIODE FIELD-STRENGTH METER, DIODE MIXER, DIODE-TRANSISTOR LOGIC, DIODE TUBE, DIODE TYPES, GUNN DIODE.



DIODE: A diagram of a diode (A) and its schematic symbol (B).

DIODE ACTION

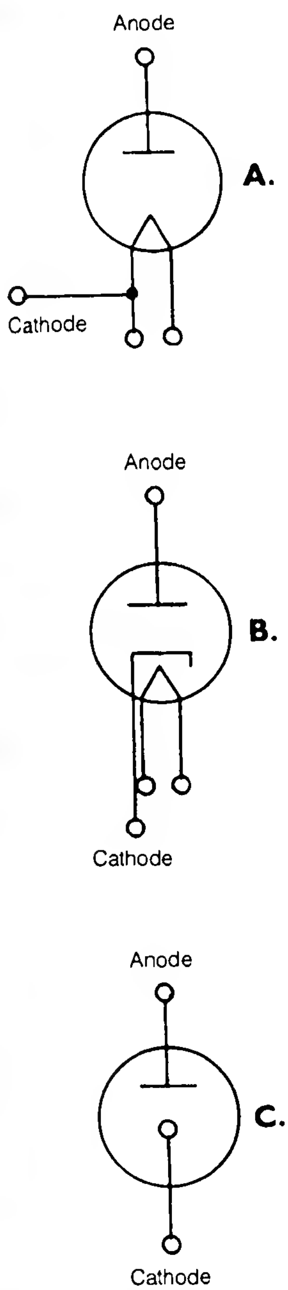
Diode action is the property of an electronic component that permits it to pass current in only one direction. In a tube or semiconductor diode, the electrons can flow from the cathode to the anode, but not vice versa. Diode action occurs in all tubes and bipolar transistors, as well as in semiconductor diodes.

DE TUBE

e tube is a vacuum tube with only two elements: a de and an anode. Diode tubes are used for the same es as semiconductor diodes; however, diode re- tubes are obsolete in modern circuits.

illustration shows the schematic symbols for di- es. At A, a directly heated-cathode tube is shown. n indirectly heated-cathode tube is shown. The t A and B require a power supply for the purpose ting the cathode. At C, a cold-cathode tube is

netrons and neon gas discharge displays are les of diode tubes used in modern electronics. *See* ON.



TUBE: Schematic symbols for diode tubes: directly heated (A), indirectly heated cathode (B), and cold cathode (C).

DIODE TYPES

There are many different types of semiconductor diodes, each intended for a different purpose. The most common application for a diode is the conversion of alternating current to direct current. Detection and rectification use the ability of a diode to pass current in only one direction.

Light-emitting diodes, called LEDs, produce visible light when forward-biased. Solar-electric diodes generate direct current from visible light. Zener diodes are used as voltage regulators and limiters. Gunn diodes and tunnel diodes can be employed as oscillators at ultrahigh and microwave frequencies. Varactor diodes are used for amplifier tuning. A device called a PIN diode, which exhibits very low capacitance, is used as a high-speed switch at radio frequencies. Hot-carrier diodes are used as mixers and frequency multipliers. Frequency multiplication is also accomplished effectively using a step-recovery diode. The impact-avalanche-transit-time diode, or IMPATT diode, can act as an amplifying device.

Details of various diodes types and uses are discussed under the following headings: DIODE, DIODE ACTION, DIODE DETECTOR, DIODE FIELD-STRENGTH METER, DIODE MATRIX, DIODE-TRANSISTOR LOGIC, GUNN DIODE, IMPATT DIODE, LIGHT-EMITTING DIODE, PIN DIODE, P-N JUNCTION, SOLAR CELL, TUNNEL DIODE, VARACTOR DIODE, ZENER DIODE.

DIP

The dual-in-line package (DIP) is a familiar type of integrated circuit. *See also* SEMICONDUCTOR PACKAGE.

In electronics the term *dip* can also refer to the adjustment of a certain parameter for a minimum value. A common example is the dipping of the plate current in a tube type radio-frequency amplifier. The dip indicates that the output circuit is tuned to resonance, or optimum condition. Antenna tuning networks are adjusted for a dip in the standing-wave ratio. A dip is also sometimes called a null (*see* NULL).

DIPLEX

When more than one receiver or transmitter are connected to a single antenna, the system is called a diplex or multiplex circuit. The diplexer allows two transmitters or receivers to be operated with the same antenna at the same time.

The most familiar example of a diplexer is a television feed-line splitter, which allows two television receivers to be operated simultaneously using the same antenna. This device must have impedance-matching circuits to equalize the load for each receiver. Simply connecting two or more receivers together by splicing the feed lines will result in ghosting because of reflected electromagnetic waves along the lines. Diplexers for transmitters operate in a similar manner to those for receivers.

Multiplex transmission is sometimes called diplex transmission when two signals are sent over a single carrier. Each of the two signals in a diplex transmission

ts of an ordinary glass jar with aluminum foil or g on the inside and outside surfaces (see illustra- A rod, generally made of brass or aluminum, s through the top of the jar, and a chain provides ctrical connection between the rod and the inner lic surface.

hen a high voltage is placed on the rod, the Leyden omes charged. It can retain a potential difference e than 100,000 volts. The Leyden jar can be used in om demonstrations. When the Leyden jar is dis- ed, the spark may jump a gap of several inches.

HT

is visible electromagnetic radiation in the wave- h range of 770 nanometers (nm) to 380 nm. (A meter is equal to a billionth of a meter.) The longest lengths appear red to the human eye, and the colors ge as the wavelength gets shorter, progressing gh orange, yellow, green, blue, indigo, and violet. e earliest theory of light held that it is a barrage of les. This is known as the corpuscular theory of and it is still accepted today, although it is known ght also has electromagnetic-wave properties. The article is called a photon. The shorter the wave- h of light, the more energy is contained in a single n.

a vacuum, light travels at a speed of about 186,282 per second (299,792 kilometers per second), the speed at which all electromagnetic fields propa- In some materials, light travels more slowly than

ght can be amplitude-modulated and polarization- lated for the purpose of line-of-sight communica- This is commonly done in fiberoptic systems (*see* TICS COMMUNICATIONS OPTICAL TRANSMISSION).

ght can be generated by thermal reactions or by means, such as ionization and lasing. Ordinary or colored light is called incoherent light because ves arrive in random phase. Laser light is called nt light, because all of the waves are in phase. *See* HERENT LIGHT, INCOHERENT RADIATION, LIGHT INTENSITY,

T-ACTIVATED ON-CONTROLLED TIFIER

activated silicon-controlled rectifier (LASCR) is a ng device activated by visible light. Incident light perform the same function as the gate current in nary silicon-controlled rectifier (SCR).

narily, the LASCR does not conduct. However, e incident light reaches a threshold intensity, the nducts. The amount of light necessary for con- is determined by the characteristics of the device the value of an externally applied bias. *See also* NTROLLED RECTIFIER.

LIGHT-EMITTING DIODE

The visible light-emitting diode (LED), also called the VLED, is the active diode in all visible light-emitting diode lamps, indicators, and displays. It is a pinhead-size PN junction made from such III-V compounds as gallium arsenide phosphide ($GaAs_{1-x}P_x$), gallium phosphide (GaP), and more recently aluminum gallium arsenide ($Al_xGa_{1-x}As$) and silicone carbide (SiC). LEDs emit light because of electron-hole recombination that takes place at the junction of the P-doped and N-doped regions. The wavelength of the light emission, also called electroluminescence or injection luminescence, is a function of the band gap of the materials from which the junction is made. *See* BAND GAP.

LEDs are grown as layered structures on an N-type substrate with an excess of freely traveling, negatively charged conduction electrons. The epitaxial layer is a P-type material with an excess of mobile positively charged electron vacancies, or holes. Metal contacts are attached to the N-type substrate and a P-type upper layer, and a forward bias (positive at the P contact, negative at the N contact) causes the electrons and holes to migrate into the active layer. As electrons are injected into the N region of the diode, they recombine with holes near the junction to create photons.

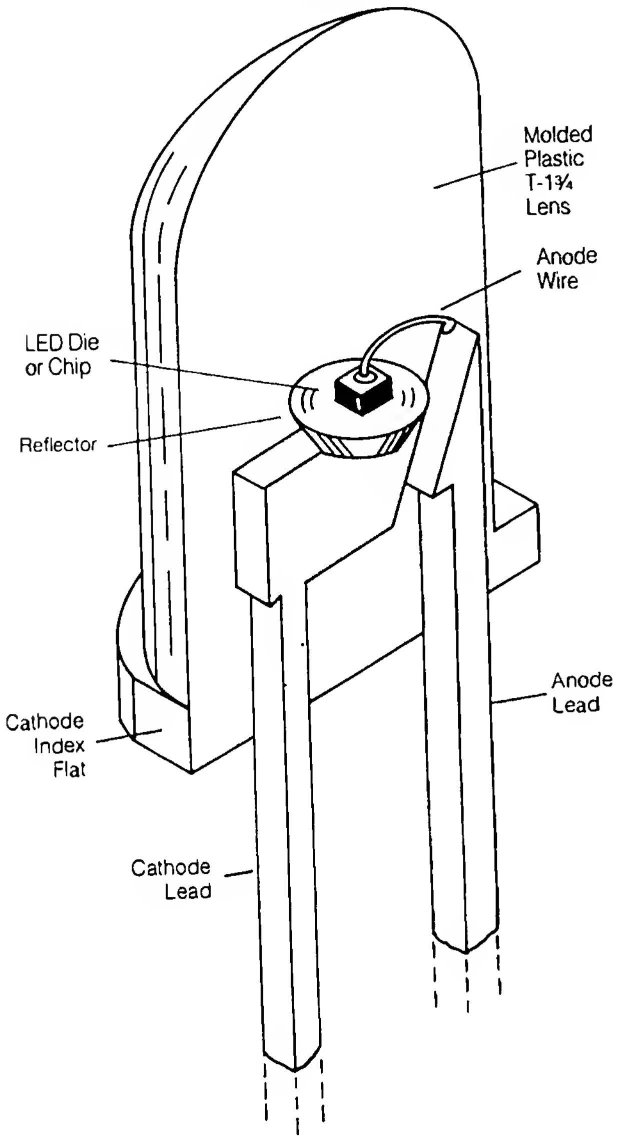
LEDs are widely used as lamps and indicators or as components of displays because of their high mechanical stability, low operating voltage, compatibility with digital logic drive circuits, ability to function at low ambient temperatures, and long service life.

Vapor-phase epitaxy (VPE) is a widely used process for manufacturing gallium arsenide phosphide (GaAsP) LEDs on a gallium arsenide (GaAs) substrate. These low-cost LEDs, mass-produced in volume, emit visible red light at a wavelength of about 648 nanometers (nm). Changing the ratio of arsenic to phosphorous and the introduction of nitrogen dopants cause the emission of yellow light at about 585 nm.

Gallium phosphide is another compound used to fabricate LEDs with liquid-phase epitaxy (LPE). Doping GaP wafers with the zinc-oxygen (ZnO) pair causes the GaP die to emit visible red light at approximately 720 nm; doping with nitrogen causes the LED to emit green light at approximately 569 nm. The electrical characteristics of GaP differs from those of GaAsP. GaP-ZnO will produce more red light at lower voltages, but it is unsuitable for multiplexing displays because of its low saturation current. Multiplexing is the sharing of switching circuitry among a string of characters in a display by pulsing the LED elements intermittently at a rate fast enough so there will be no apparent flicker.

High-efficiency LEDs that emit visible red light are being made with VPE growth of GaAsP-on-GaP substrates. The emission color is determined by the ratio of arsenic to phosphorous. The visible red emission of these LEDs is approximately 626 nm. The same technique is used to produce orange emission at 608 nm and yellow at 585 nm.

In another recent development, aluminum gallium arsenide (AlGaAs) is used to produce LEDs that emit red



LIGHT-EMITTING DIODE: An LED lamp is a die attached to a reflector on a cathode lead and wire bonded to an anode lead. The molded protective plastic lens determines the viewing angle and lamp brightness.

light at about 646 nm. These LEDs are made by a double-heterojunction AlGaAs process. They can operate at lower currents than existing high-efficiency red materials. An N-type AlGaAs confining layer, a P-type AlGaAs active layer and a P-type AlGaAs confining layer is grown on an N + GaAs substrate. Both high-efficiency and AlGaAs LEDs are suitable for display multiplexing because they offer the higher brightness of GaP with the linear light-versus-current characteristic of GaAsP.

LEDs that emit visible blue light at 475 nm are being made with silicon carbide (SiC). This is the only material that allows reproducible P and N doping and has a band gap for emitting blue light. The blue wavelength of SiC is achieved by doping the diode with aluminum and nitrogen in an LPE process. These LEDs are used as color calibration sources for TV cameras and photographic equipment and as light sources for medical equipment.

Because the light output or luminous intensity of LEDs is generally proportional to current, alteration of the bias voltage can modulate light output. Changes of LED light output of about 2:1 are necessary for detection by the human eye so that slight variations in bias voltage will not be noticed. But, the human eye can easily detect minor light output differences between two adjacent LEDs.

Individual LEDs are packaged in a wide variety of cases with some form of optical lens. In the most common packages the dies are mounted on radial lead frames and molded in a bullet-shaped plastic form as shown in the figure. The lens may be diffused or nondiffused, and it can be tinted in specific color such as red, yellow or green.

The most widely purchased case styles are the T-1 and T-1 ¾ radial-leaded plastic packages. Other packages include flat top and surface-mount styles as well as rectangular molded cases, which produce rectangles of light from their end surfaces. For military and high-reliability applications, LEDs are usually packaged in hermetically sealed TO-5 style metal cases with a glass lens at the top.

The forward bias voltages for most LEDs are from 1 to 2.3 V, but the blue light emitting LED requires 5 V. Typical luminous intensity for LEDs is measured in millicandela (mcd) at currents of 2 to 20 mA. Viewing angles (angles within which the luminous intensity is least half the axial value) vary from 18 to 150 degrees.

Viewing angle is important in LED applications because a lamp with a wide viewing angle can be seen wh viewed from large offset angles. However, a LED wi narrow viewing angle appears brighter because the lig is concentrated in a narrower beam. *See* LIGHT-EMITT DIODE DISPLAY.

LIGHT-EMITTING DIODE DISPLAY

Light-emitting diode (LED) displays are assemblies individual LED diodes on a rigid substrate to form on more alphanumeric characters. The displays can be mented or dot-matrix displays. Segmented displays form all numbers and some letters but dot matrix plays are capable of forming all of the ASCII charac LED displays are used in a wide range of applica from readouts for consumer clocks and applia (washing machine, microwave ovens, etc.) to read for aircraft instruments and industrial controls. W fitted with decoder and driver circuitry, LED dot-m displays have become peripheral equipment for co ers capable of one or two lines of text.

Seven-segment (figure 8) display modules as in the illustration permit the formation of all nu and uppercase letters A through E. Each of th elements is illuminated by an individual LED. S segment LED displays are able to form 64 of the characters. A 5-by-7 dot matrix of individual LED mits the formation of all 128 ASCII characters in numbers, upper- and lowercase letters, and othe bols.

The LED dies are bonded to a common con surface. This could be a metal lead frame as illustra